PB-217 452

STUDY OF PULP AND PAPER MILL POLLUTION IN PUGET SOUND

A. F. Bartsch

Pacific Northwest Water Laboratory
Corvallis, Oregon

1965

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

Study of pulp and paper mill pollution in Puget Sound. In E. A. Pearson, ed., Advances in water pollution research. Proceedings of the Second International Water Pollution Research Conference, Tokyo, August, 1964. Pergamon Press, New York. pp. 43-64.

REPRINTED FROM PB 217 452

The Proceedings of the Second International Water Pollution Research Conference, Tokyo 1964

PERGAMON PRESS 1965

NEW YORK · OXFORD · EDINBURGH · PARIS · FRANKFURT

STUDY OF PULP AND PAPER MILL POLLUTION IN PUGET SOUND

A. F. BARTSCH

Pacific Northwest Water Laboratory
Division of Water Supply and Pollution Control, Public Health Service
U. S. Department of Health, Education, and Welfare, Corvallis, Oregon

INTRODUCTION

To seek the solution of a long-standing and difficult water pollution problem, the State of Washington asked assistance of the U. S. Department of Health, Education, and Welfare under provisions of the Federal Water Pollution Control Act. Accordingly, a formal conference, held as a step in the legal proceeding, concluded that remedial measures taken to date have not been sufficient to control pollution and that corrective actions have been delayed. The conferees recommended that a joint action program be undertaken by the State and Federal governments.

The program has been under way since spring 1962. Among its several phases are field studies at four locations where seven pulp and paper mills discharge wastes into Washington's Puget Sound waters. Because of its varied aspects, the program is an excellent example of blending a wide range of disciplinary skills and bringing them to focus on a common objective. The total effort represents cooperative participation by the U. S. Government; the Washington State Pollution Control Commission; State fish and game departments; universities; and industries.

This paper reports the findings of essentially the first year's field research at one of the four study sites—namely, Everett. It also identifies problems encountered and describes new procedures found necessary. The program objective is to determine the effects of wastes from the pulp and paper mills on the marine environment and its harvestable resources.

Some of the four problem areas already have been studied with varying intensity by State regulatory agencies, universities, and industries.[1] In similar marine waters in neighboring British Columbia, WALDICHUK[2] has made extensive studies of pulp and paper mill pollution. Puget Sound studies, to date, have not clearly delineated the effects of waste discharges or determined precisely the corrective steps needed. To ascertain the facts concerning these industrial wastes and their effects, the study program has been made as comprehensive as the available resources permit. It consists of four major elements—in-plant waste surveys, oceanographic studies, biological studies, and economics studies.

IN-PLANT SURVEYS

Of the seven mills at issue, one is located at Bellingham, one at Anacortes, three at Everett, and two at Port Angeles. Collectively, they have a daily capacity of about 1814 metric tons of sulfite pulp plus a little more than 180 metric tons of ground wood

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. Department of Commerce
Springfield VA 22151

and sulfate pulp. The wastewaters discharged from these mills impose a 5 day, 20 C biochemical oxygen demand (BOD) load of about 450,000 kg on the receiving waters of Puget Sound.

In-plant surveys, initiated early in 1963, are under way at each of these mills to evaluate more precisely the specific waste streams originating in the major processes at given production levels. Each mill is studied on three occasions over a time span of 18 months so that a normal range of production activities will be reflected in the results. Data from the later surveys also will reflect improvements in waste handling now being instituted by the industry managements. Each survey covers a three-day period during which waste stream samples are composited manually or mechanically for the following analyses: pH, Pearl-Benson Index (PBI)*; BOD; sulfur, where indicated; total and fixed solids; and suspended solids, both total and fixed before and after settling. To date, one survey has been completed in each of the two sulfite mills located at Everett. Pulp mill waste production in these mills and related summarized information for the three-day survey period are as follows:

		Metric tons		
	Production	Total solids	Suspended solids	BOD
Total day for both mills	957	1656	23·39	449
kg metric ton production per day		1730	24·4	469

As a further step in waste characterization during the next survey, the wastes will be examined through oyster larva bioassay following a procedure described in a later section.

Wastewaters from these mills are discharged into the surface waters of the inner harbor at Everett and through a submerged outfall to Port Gardner Bay. Surface discharges are mainly log barking wastes, white waters from pulp and paper machines, and bleach plant effluents. SWL from the two mills flows to a surge tank through a single pipeline and is then discharged through a submerged outfall 914 m long. The last 305 m consist of a multiple-port diffuser line with the upper part lying in 91 m of water and the lower part in 104 m. According to in-plant survey data, volume of total daily discharge by way of the submerged outfall is approximately $78{\cdot}7 \times 10\ m^3$. It contains 1452 metric tons of total solids, 3·94 metric tons of fiber, and 417 metric tons of BOD.

OCEANOGRAPHIC STUDIES

Oceanographic studies have the objectives of finding where the pulp mill wastes go, what mechanisms of dispersion, tide, and current are available to dispose of them, and how long they persist in the environment. These studies also detect and measure

* PBI — dilution of sulfite waste liquor (SWL) containing 10% solids expressed as p.p.m. by volume; determined by BARSES *et al.*[6] modification of the PEARL and BENSON[7] technique. Although not synonymous, the terms PBI and SWL will be used interchangeably.

effects of wastes on the marine environment—both the chemistry of the water and composition of the bottom. Waters under study at Everett are Possession Sound, Port Gardner, Port Susan, and Saratoga Passage (FIG. 1).

FIG. 1. Everett, Washington area of Puget Sound showing oceanographic sampling stations, August 2 and 3, 1962.

Puget Sound tides, of the mixed, twice-daily type, essentially retain characteristics of the generating tide at sea but are affected by basin geometry and related influences. At Everett, the mean tide range is 2.26 m, and the diurnal range is 2.19 m. The mean volume required to fill Puget Sound from low to high water during a tide cycle is about 1.27 cubic nautical miles. A similar estimate for the Everett area alone gives a mean tidal volume of 195 million m^3, or 0.03 cubic nautical mile. This is the amount of water available for dilution and mixing of water already in the area when filling starts. How efficiently it is used in dispersing wastes is not yet known.

At monthly intervals, hydrographic stations were occupied along nautical-mile points located radially from the end of the submerged outfall. Water samples were collected in Teflon-coated Nansen bottles, from depths of 0, 5, 10, 20, 30, 50, 75, 100, 125, and 150 m, depth permitting. As in the in-plant surveys, SWI concentration was determined by a 1963 modification[7] of the PEARL–BENSON technique. This tech-

nique measures the lignin content of wastewater originating in the pulp mills. Temperature, salinity, dissolved oxygen (DO), and pH were measured routinely from the same Nansen bottle from which the PBI sample was obtained. DO was determined by the Alsterberg (azide) modification[7] of the Winkler test. The RENSHELL test[8]

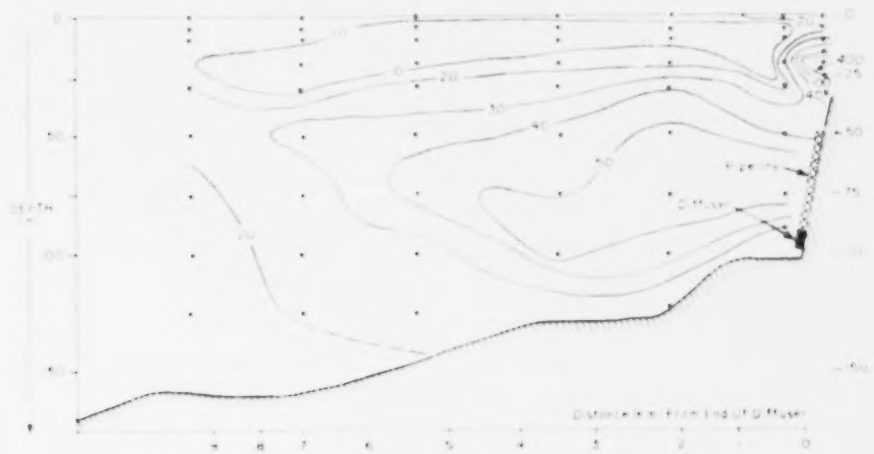

FIG. 2. Vertical distribution of PBI (p.p.m.) along a plane from the pipeline to Saratoga Passage, August 3, 1962.

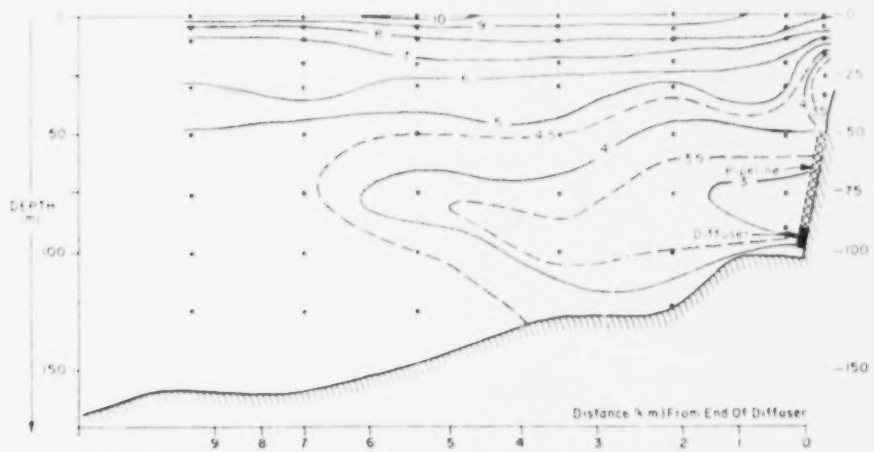

FIG. 3. Vertical distribution of dissolved oxygen (mg/l.) along a plane from the pipeline to Saratoga Passage, August 3, 1962.

of the effect of SWL on the azide determination of DO showed no lowering of DO at the SWL concentrations encountered.

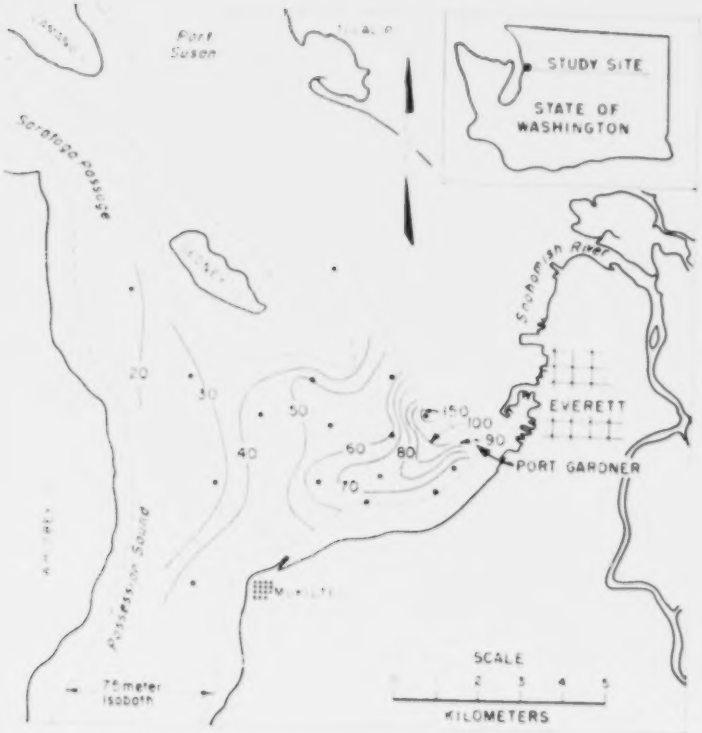

FIG. 4. Distribution of PBI (p.p.m.) at 75 m depth, August 2 and 3, 1963.

A vertical section of PBI concentrations along the line connecting hydrographic stations shown in FIG. 1 is given in FIG. 2. These data, which are typical, show extension of SWL from the submerged outfall into Saratoga Passage. There is a pronounced tongue (PBI at 50 p.p.m.) extending 4 km from the diffuser at about 75 m depth. The tongue gradually rises to about 40 m where the concentration diminishes to 22 p.p.m. at 8 km. Also shown is a secondary tongue of SWL at about 20 m, reaching a concentration of 400 p.p.m. Corresponding oxygen distribution along the same section is shown in FIG. 3. Plume depths and configurations of low DO and high PBI concentration are similar.

A horizontal section of PBI occurring at 75 m during the same cruise is shown in FIG. 4. The tongue extending into Possession Sound is pushed north of the pipeline by tidal currents existing at the time. The position of the isopleths of PBI indicates that the net current is into Saratoga Passage with little tidal mixing northeast of Mukilteo. At this time, the surface waters in the area had PBI concentrations of 10 to 20 p.p.m. over more than 35 km².

Although intensive current studies have been made at Bellingham and Port Angeles, only limited observations have been made thus far at Everett using current drags

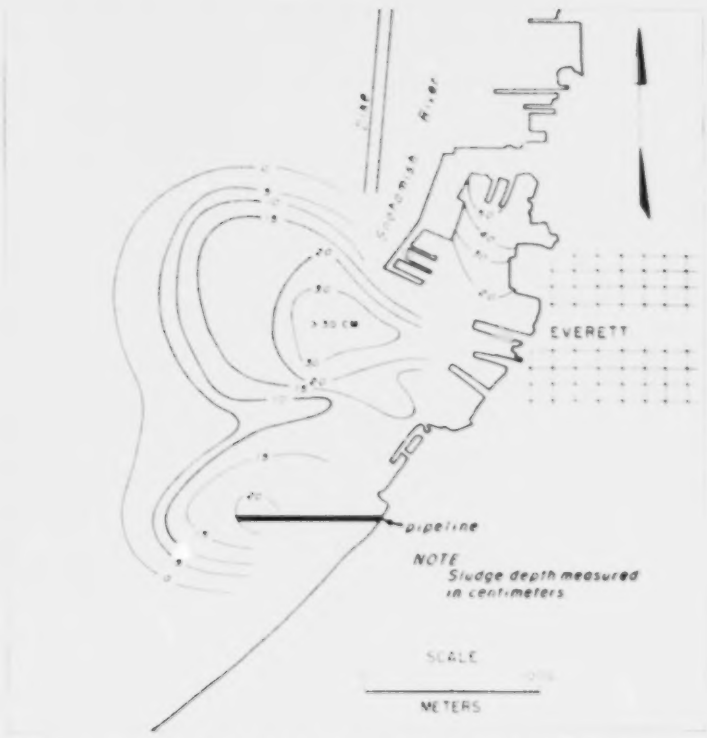

Fig. 5. Distribution and thickness of sludge deposits in Everett Harbor and Port Gardner Bay.

suspended from marker buoys. Surface currents are not now well known in the Everett area, but current direction at depth can be inferred from the hydrographic data thus far collected. During spring 1964, Richardson current meters will be used extensively at Everett. Upon completion of this work, it will be possible to delineate the waste flushing characteristics of the area.

To determine the horizontal extent, depth, and composition of bottom deposits in Everett Harbor and Port Gardner Bay, both clam-shell, snapper and gravity core samples were taken at numerous stations at depths of 7–171 m (Fig. 5). The upper layer of the sediments was found to consist of fine-grained, flocculent mud containing disseminated sand grains, wood fragments of all sizes, wood fibers apparently of pulp mill origin, and other organic material. The sediments were black and malodorous, had H_2S odor indicative of oxygen deficiency, and an abundance of wood materials. They lacked appreciable macroorganism populations. Percent volatile solids content on a dry weight basis was highest near the waste discharge points, ranging from 11·0 to 54·0 per cent in nearby Everett Harbor and from 1·6 to 12·4 per cent in more distant Port Gardner Bay. Selected samples are being examined further using the Graff[7] microscopic and staining technique to identify wood fibers and the

pulping process in which they were produced. Underlying the deposits was a layer of olive-gray, homogeneous mud and coarse sand, contrasting sharply with the overlying deposits.

BIOLOGICAL STUDIES

The principal marine organisms harvested in the Everett area are four species of salmon (*Oncorhynchus tshawytscha, O. kisutch, O. keta, O. gorbuscha*), steelhead trout (*Salmo gairdneri*), bottom fish, and crabs. Values for selected fisheries are given below. Biological studies are designed to evaluate direct effects of pulp and paper mill wastes on these resources and on the environment in which they live.

Fishery harvest in Snohomish River–Port Gardner area, 1962*

	Number	Value ($)	Kind of fishery
Crabs	15,639	9808	Commercial
Salmon	63,228	542,365	Sport & commercial
Steelhead	22,930	220,930	Sport

Data collected to date show that downstream-migrating juvenile salmonids from spawnings in the Snohomish River invade waters of suspect quality along the Everett water front. Eight *in situ* bioassays at one or two depths at 23 stations in this area showed that conditions were at times inimical to juvenile salmon, with most mortalities occurring near the points of waste discharge. Mortality distribution for a typical study period is shown in FIG. 6. Concurrent temperature, salinity, and PBI were at levels less than those expected to cause acute toxicity. On occasion, mortalities were concurrent with free chlorine concentrations of 50 p.p.m., with sulfide concentrations up to 0.5 p.p.m., or DO concentrations approaching zero. Mortalities were most pronounced during early rising stages of the first several spring tides and more frequent in the surface waters than in the deeper waters. New waste handling procedures now being provided by the mills will help eliminate these adverse water front conditions.

While the number of Snohomish River salmon entering Everett Harbor appears substantial, data available from past sampling are not sufficient to permit a sound estimate. During spring of 1964, further study will determine the number of fish in the river system, the percentage entering the harbor, and the duration of residence in areas of adverse water quality. To accomplish this, the sampled migrating population in the river will be estimated as fish per unit stream discharge. Concurrently, dye-marked fish will be released in the harbor so that programmed sampling will permit estimating the proportion of river migrants entering the area. Fish-dyeing studies, to date, show that rhodamine B, Bismarck brown, Sudan black, and atabrine fed in pellets may be suitable for marking. Residence time will be determined by using different colors on subsequently spaced fish releases and recaptures. The re-

* Source of information: Washington State Department of Fisheries; includes pink salmon (*O. gorbuscha*) harvest for 1961.

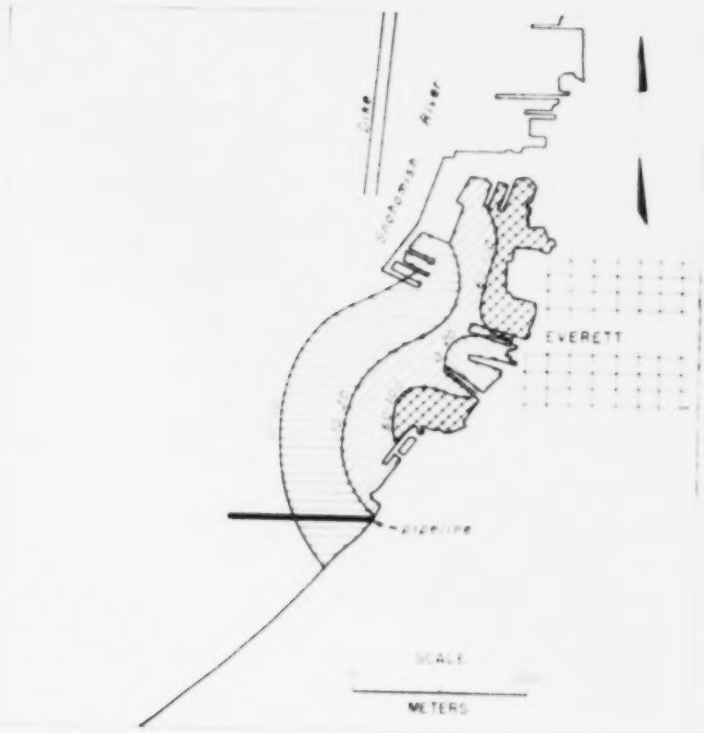

FIG. 6. Zones of toxicity to juvenile salmon in Everett Harbor—per cent mortality in 24 hr, composite of 6 tests.

sulting information will permit estimating the number of fish and proportion of the season's total migrants that enter the area and are threatened by the locally adverse water front conditions.

A less common procedure used to characterize water quality depends on observing oyster larva development. Water samples were collected monthly by seaplane from a total of 60 stations in the four problem areas in Puget Sound. Each was subjected to larval bioassay within 3 hr of collection using a technique developed by LOOSANOFF and DAVIS[1] as modified by WOELKE.* The flow diagram of the procedure (FIG. 7) shows that analyses were made for initial and terminal PBI and salinity concentrations. Chlorophyll-*a* was measured in the raw samples.

Oysters are not cultivated or commercially harvested in the vicinity of Everett. Therefore, although larval bioassays have been made routinely with samples collected there, results will be discussed for Bellingham Bay and adjacent waters some 88 km to the north, where 255,360 L of unshucked Pacific oysters (*Crassostrea gigas*)

* This phase of the program is a cooperative undertaking with the Washington State Department of Fisheries Shellfish Laboratory, Point Whitney.

OYSTERS
CONDITIONING
4 - 6 Weeks at 20° C.
SPAWNING
Temp. raised to 25° - 30° C. for 2 - 3 hours, sperm added.
INOCULATION
20 - 30 Thousand zygotes, 1 - hours old or less, added to each culture.
WATER
CARRY - ALONG
4 Liter sea water from laboratory.
COLLECTION
4 Liter sample by seaplane.
TRANSPORT
All samples to laboratory within 3 hours of collection.
3 ONE - LITER CULTURES
Incubated at 20°C for 48 hours.
CHLOROPHYLL
500 ml.
TERMINAL S. W. L. AND SALINITY
250 ml.
ALIQUOT SAMPLE
Containing 100 - 200 larvae.
INITIAL S. W. L. AND SALINITY
250 ml.
INDEX
Percent abnormal larvae determined.

FIG. 7. Flow diagram for oyster larva bioassay.

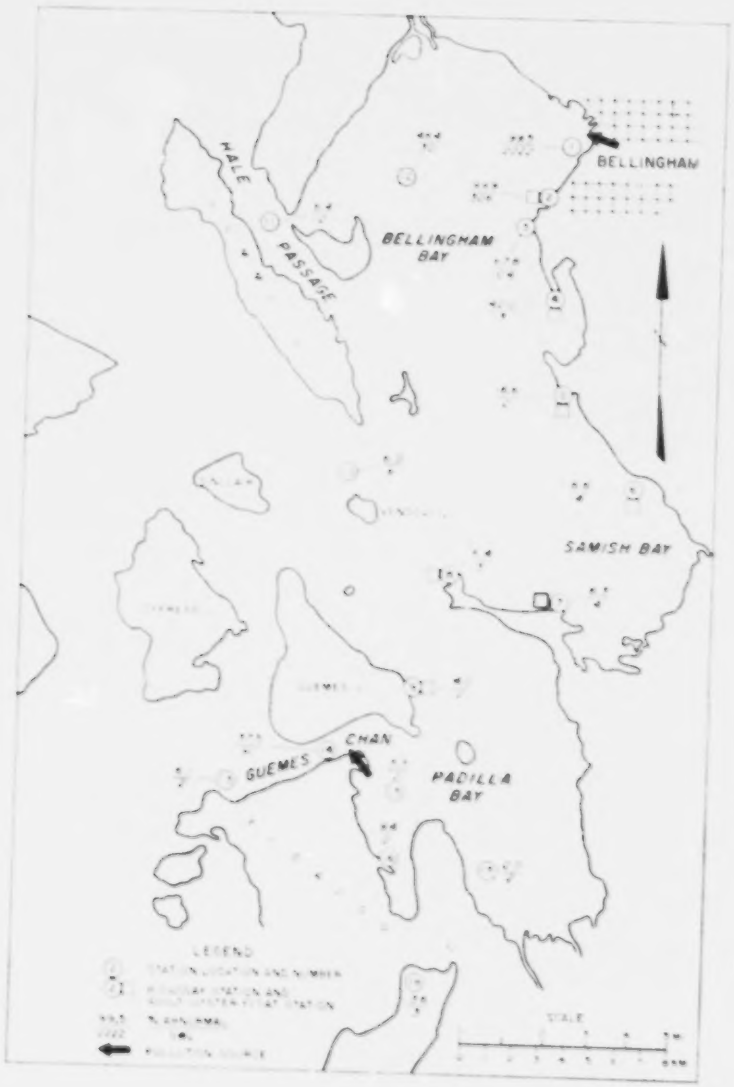

FIG. 8. Oyster larva biomass data for upper Puget Sound—summary for May–October 1964.

are harvested annually. Bellingham is the site of a 453 metric tons per day sulfite pulp mill that discharges a daily total waste volume of $11{\cdot}6 \times 10^4$ m^3. Oyster growers claim that these wastes damage the shellfishery.

Preliminary bioassay results from the first six months of sampling show increasing abnormalities among the test larval populations with decreasing distance from the waste sources (TABLE 1, FIG. 8). From past experience, it is felt [12] that more than 50 per cent abnormalities mark the lethal threshold for the variable tested; 90 per cent show a clearly lethal condition.

Long-term, adult oyster bioassays are in progress at seven locations (FIG. 8) to determine mortalities, growth rate, and condition index or market quality. Initially, the oysters were held in asphaltum-coated metal mesh baskets supported in 2·4 × 3 m anchored rafts. Test populations consisted of 50 pieces of seed cultch, 150 1-year-old and 100 2-year-old Pacific oysters. Additional specimens were suspended on wire for condition index determinations at quarterly intervals. Turbulence during storms jostled the oysters, interrupted their feeding, and raised questions concerning other less obvious effects so that test conditions were unacceptable. After four months, this bioassay program was aborted. An acceptably stabilized float system was then developed as a prerequisite to a new bioassay program initiated in January 1964. To be most meaningful, this program will have to be carried on for two years to bring the initially young age class to marketable age.

TABLE 1. OYSTER LARVA BIOASSAY DATA FOR UPPER PUGET SOUND SUMMARY FOR MAY—OCTOBER 1963

Station	Meters from pollution source	Average PBI (p.p.m.)	Per cent abnormal
Control	—	1	2·5
1	90	2222	99·5
2	3020	306	99·9
3	4570	104	67·8
4	7590	13	42·0
5	10,700	2	16·6
6	13,900	4	8·6
7	18,100	4	6·3
8	17,920	3	6·4
9	22,490	2	4·0
10	11,060	6	6·0
11	11,610	12	6·4
12	6680	30	48·4
13	4570	2	6·1
14	820	91	37·5
15	2060	2	5·5
16	4620	2	9·4
17	6680	2	2·0
18	—	3	3·6
"Carry-along"	—	1	8·7

Several other biological activities currently contribute to ecological knowledge of the Everett area. These include periodic sampling for benthic invertebrates, zooplankton, and phytoplankton. Only preliminary interpretations are now available from these studies. Beginning in early summer 1964, these waters will be examined to determine if basic productivity is influenced by pulp mill pollution. Standing crop will be estimated from determination of plankton pigments, and rates of carbon fixation will be determined by C14 and light and dark bottle techniques.

ECONOMIC STUDIES

Both contractual and intramural economic studies have been designed to assess the impact of acceptable waste disposal by the industry, or lack of it, on the economy of the Puget Sound area. Although 1960 employment in pulp and paper production was a little more than 1 per cent of the area's total, relative importance of this employment is expected to decline. Population growth rate, on the other hand, likely will grow 2.4 per cent per year, indicating a rapidly increasing demand for various uses of Puget Sound waters. Comparable monetary values cannot be assigned to all water uses. Useful perspective, however, is found in such estimates as the gross value of sport salmon fishing at $50 $60 million annually, and the use of Puget Sound's state parks by 3.5 million visitors in 1961.

Waste treatment considerations also indicated that although initial expenditure for treatment facilities would be substantial, the incremental cost per ton of production would be minor. When considering other alterations of the cost price relationship borne in the recent history of the industry, treatment costs should not be a material factor in decisions to expand or contract regional pulp production.

CONCLUSION

Each element of the investigative program is like one of many strands of a web. While each by itself has only limited meaning in sensing waste influences on the environment, the full strength lies in the whole and the way its parts are woven together. To make this product possible requires the abilities of several professional disciplines. Seeing them work together toward this common goal is a stimulating adventure in water quality management.

REFERENCES

[1] Wagner R.A., Zibell C.D. and Livingston A. 1957 Pollution investigation in northern Puget Sound, *Tech. Bull.* 22, Washington Pollution Control Commission.

[2] Peterson D.R. and Gibbs C.V. 1957 Investigation of pollution in Port Angeles area, *Tech. Bull.* 23, Washington Pollution Control Commission.

[3] Tollefson R. 1963 Basic biological productivity in a marine industrial area, *J. Water Poll. Control Fed.* **35**, 989–1005.

[4] Stein J.E., Denison J.G. and Isaac G.W. 1963 An oceanographic survey of Port Angeles Harbor, *Oregon State Univ. Eng. Exp. Sta. Circular* **29**, 172–202.

[5] Waldichuk M. 1960 Effects of pulp and paper mill wastes on the marine environment, *U.S. Public Health Service Robert A. Taft Sanitary Engng. Center Tech. Rep.* W60-3; 160–176.

[6] Barnes C.A., Collias E.E., Felicetta V.F., Goldschmid O., Hrutfiord B.F., Livingston A., McCarthy J.L., Toombs G.L., Waldichuck M. and Westley R. 1963 A standardized Pearl-Benson, or Nitroso, method recommended for estimation of spent sulfite liquor or sulfite waste liquor concentration in water. *TAPPI* **46**, 347–351.

[7] Pearl I.W. and Besson H.K. 1940 A nitrosolignin colorimetric test for sulphite waste liquor in sea water. *Paper Trade J.* **111**, 35–37.

[8] APHA 1960 *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes*. (11th ed.) pp. 309–311. American Public Health Assoc., Inc.

[9] Renneriet J. 1955 Bestämning av Löst syre I Sulfitluthaltiga Valtendrag. *Sartruck ur Svensk Papperstidning* Nr 3. 3 pp.

[10] Graff J.H. 1940 *Color Atlas for Fiber Identification*. Institute of Paper Chemistry, Appleton, Wisconsin.

[11] Loosanoff V.L. and Davis H.C. 1963 Rearing of bivalve mollusks. *Advanc. Marine Biol.* **1**, 2–80.

[12] Woelke C.E. 1961 Bioassay—the bivalve larvae tool. *Proc. 10th Pacific Northwest Symp. on Water Pollution Res.* pp. 113–123. U. S. Public Health Service.

FORMAL DISCUSSIONS

J. E. McKEE and W. R. SAMPLES

(*W. M. Keck Laboratory of Environmental Health Engineering, California Institute of Technology, Pasadena, California, U.S.A.*)

THE objectives of the investigation described by Dr. BARTSCH are commendable, for present knowledge about the effects of pulp and paper mill wastes on aquatic, estuarine, and marine environments is sparse indeed. The comprehensive data-gathering program in Puget Sound should provide considerable insight relative to the complex ecological relationships among wastewaters and estuarine life. Engineers and scientists will await the final report of this investigation with considerable interest and hope.

Dr. BARTSCH has been placed in the unfortunate position of reporting largely on research that he expects to undertake. Very little had been accomplished at the time this paper was written and reviewed. Hence, the author had few original data with which to report. There are advantages, however, in discussing a proposed project rather than a completed one, for any pertinent criticisms can thus be incorporated into the research plan. With this in mind, the discussors have taken the liberty to point out areas that may have been neglected or overlooked by previous and present investigators.

Despite the obvious need for this investigation, it should be recognized that Puget Sound has already been studied extensively in many ways, especially by oceanographers and marine biologists. The University of Washington, for example, has a hydraulic model of the estuary with which flushing characteristics have been studied. It is to be expected that Dr. BARTSCH and his colleagues will make a thorough review of all existing data to supplement their own investigations.

The subject paper is divided into four major parts: (a) in-plant waste surveys, (b) oceanographic studies, (c) biological studies, and (d) economic studies. This discussion will generally follow the same headings.

1. *In-plant surveys.* The analyses of samples from waste streams include the spectrum of solids determinations, 5-day BOD, pH, SWI, and sulfur where indicated. It would be advisable, however, to extend these analyses to include 50- and 100-day BOD values, chemical oxygen demand (COD), the nitrogen constituents, phosphates, and especially the heavy metals. Owing to the nature of the chemical processes employed in pulp and paper mills, and the metals used for piping, it is not uncommon to find appreciable concentrations of copper, zinc, lead, nickel, titanium, and vanadium in such wastewaters. These heavy metals may accumulate in the biota and reach toxic concentrations. The nitrogen constituents and phosphates are significant in that they strongly influence the biological productivity of the receiving waters.

There are some inconsistencies in Dr. BARSTCH's data on production and BOD loadings as to whether they refer to the seven mills in the entire survey or only to the two surveyed mills (of three) at Everett.

2. *Oceanographic studies.* The slow rate at which SWL decomposes makes it an excellent tracer for estuarine investigations. FIGURES 2 and 4 of the subject paper show clearly the dispersion pattern of SWL discharged at Port Gardner. The reader should recognize, however, that the Pearl-Benson test does *not* measure SWL in mg l as shown in FIGS. 2 and 4 or in the text of the subject article. Instead, it indicates parts million by *volume* of a sulfite waste liquor containing 10 per cent solids by weight. On a purely gravimetric basis, the data shown as mg l of SWL on FIGS. 2 and 4 and in the text should all be divided by 10. In reporting the results of Pearl-Benson analyses, it is best to record them as P-B Indices (PBI). Thus, a PBI of 50 represents 50 p.p.m. by volume of a 10 per cent SWL, and corresponds to 5.0 mg l of SWL on a dry basis.

3. *Biological studies.* The only results reported of a biological nature concerned a series of *in situ* bioassays along the Everett water front using juvenile salmon. The use of *in situ* bioassays to study a problem of pollution covering a relatively small area does not allow for any "avoidance reactions" on the part of the fish. This is an important defensive mechanism for fish against many types of pollutants.

Dr. BARTSCH outlines a detailed program for the spring of 1964 that will allow an estimate to be made of the effects of waterfront conditions at Everett on salmon. If this pollution is indeed detrimental to fish then some estimate of the number killed each year should be available or obtained for the coming years.

Extensive bioassays have been conducted by several investigators with SWL in relation to oyster larvae and adults. They are summarized as of 1959 by GUNTER and MCKEE. The big gap in knowledge relates not to bioassays with oysters but rather to the direct and long-term effects of SWL on plankton, especially nannoplankton such as the naked flagellates that constitute the primary food of oysters. It is possible that the nutrients associated with SWL stimulate the productivity of nannoplankton; but SWL may be directly toxic to certain sensitive forms. Dr. BARTSCH and his colleagues would be well advised to concentrate their biological investigations on the relationship between SWL and nannoplankton.

4. *Economic studies.* This phase of the proposed investigation may well prove to be the most significant, especially insofar as public policy is concerned. Oyster growers, for example, have blamed the pulp and paper industry for many of the difficulties besetting oyster production. Yet, over the past two decades, the yield of Pacific oysters in Puget Sound and Grays Harbor, both areas being subject to SWL, has tended to increase although the production of Olympia oysters has declined markedly in these areas. In contrast, oysters along the east coast and Gulf coast of the U.S.A. have fared badly in the past two decades. Expressed otherwise, oysters have survived and thrived better in the SWL-receiving waters of the Pacific Northwest than in the SWL-free waters of the east and Gulf coasts. It is apparent, therefore, that oystermen and marine ecologists should look farther than the nearest pulp and paper mill to diagnose the many ills besetting the oyster industry.

On the other hand, gross pollution by the pulp and paper industry is inexcusable. Where dissolved oxygen is seriously depleted, where sludge banks and benthic deposits become objectionable, where productivity of the estuary is markedly reduced, and where esthetic and recreational values are diminished, the economic factors may weigh heavily against the pulp and paper industry. Experience indicates, however, that heavy industry can exist and prosper side-by-side with recreational values and marine life if all parties are willing to cooperate and adopt reasonable attitudes.

REFERENCES

GUNTER G. and MCKEE J.E. 1960 On oysters and sulfite waste liquor. Washington Pollution Control Commission, Special Report.

TADAO NITTA

(Tokai Regional Fisheries Research Laboratory, Tokyo, Japan)

THE peculiarity observed in the water pollution problem in Puget Sound may be due to the geographical features and the condition in which the polluted water is discharged.

The polluted area of Puget Sound is wider than those in Japan. The water, with a lower oxygen content, covers a large expansion of the bay. Therefore, it is supposed that Puget Sound is a wide and deep bay, with very little exchange of the water mass. In addition, the polluted water discharged along a deep layer about 100 m below the surface is suspended there for a long time.

In this paper, no discussion is given about the exchanging mechanism of the sea water and the suspending period of the polluted water. It may be an interesting exercise for studying the problems in Puget Sound.

In many cases known to us the influence of the polluted water may follow such a process as this: Polluted water, when discharged near the surface of the coastal sea, forms a water mass on the surface. (Now we must deal with waste water which was initially fresh water. In the case of the pollution of the sea water used as cooling water, for instance, the influence is not the same as explained here.)

The following are characteristics of the water mass polluted by a certain paper mill in Japan:

1. The area of the water mass had positive interrelation with the volume of discharged water (FIG. 1). Though the pollution survey was conducted on several different occasions, the expansion of the area measured was not the same every time. The mean value of those areas is plotted on the interrelation line of the figure.

2. The depth of the water mass was about 0.5–2 m, and the horizontal expansion of the mass was changed by the hydrographic conditions or discharging condition of the polluted water.

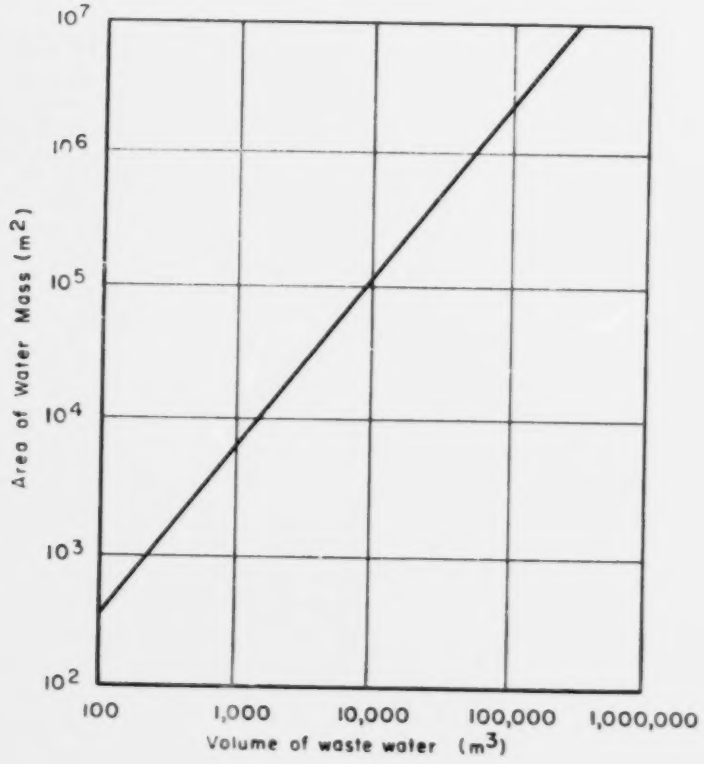
10^7
10^6
10^5
10^4
10^3
10^2
Area of Water Mass (m^2)
100
1,000
10,000
100,000
1,000,000
Volume of waste water (m^3)

FIG. 1.

3. The concentration of the polluted water in the water mass is diluted about 10–20 per cent at points near the outfall of the factory, and about 1–2 per cent in front of the waste water mass.

4. Waste water discharged from the factory flowed through the water mass and reached its front within two hr. (In several examples, the discharge of waste water was up to 100,000 MT day.)

5. In an area immediately connected with the open sea, we cannot chemically detect the waste water out of the water front. But in a bay where the sewers have outfalls, turbid or colored water influenced by the waste water would be seen.

No reference is given in the paper as to the volume of waste water of Puget Sound. But if the volume of waste water is 400,000T day as estimated from the pulp production of 2000 MT day, the water mass may have the semicircle area of about 2500 m in radius, with the depth probably about 2 m, as in the normal cases known to us. In many cases, the area of the polluted water mass is a little wider than the area of the polluted bottom deposit. The area of the waste water in Puget Sound may have nearly the same expansion as sludge distribution shown in the report. The question of why the influence of the waste water is so wide in Puget Sound is very interesting for us to study as a different water pollution problem.

The next problem of pollution is its biological aspects. In this report the bioassay of juvenile salmon and oysters is related, along with their mortality. Besides, investigative plans of benthic invertebrate and plankton are mentioned.

One point I want to make here is that in case of the influence which pollution may exert upon commercially useful animals in the coastal sea, the problem involves not so much mortality but avoidance reaction.

In our survey of pollution we followed two procedures: 1. the examination of living organisms which must commonly exist in every part of the sea, and 2. The distribution of the useful nektons.

In our plan, the first item includes plankton and benthos on the bottom, bank, and beach. Sometimes when the concentration of waste water is exceedingly high, there exist no zooplankton, most probably due to their avoidance reaction. Abnormal distribution of benthos often found at the bank or beaches near the outfall of sewers may be due to the mortality. It is known that the benthos on the sea bottom are in close relation with the bottom composition. There are many special animals that mark the pollutions of the bottom layers. Take for instance, *Capitella capitata* or *Lumbriconereis impatience*. Reference to the status of these organisms enables us to determine the degree of pollution and the changes of the bottom characters.

To investigate the distribution of the nektons we use two methods: (a) The use of fish finders enables us to examine the distribution of fishes minutely and (b) Experimental fishing with fishing gear fitted for the purpose. Not only the artificial environment but also the natural one has a great influence upon marine organisms. When both influences are combined by chance, they often give a fatal effect to living. Therefore, we have to be very careful in deciding whether or not the influence of pollution exists to any degree. In any event, however, when and where an influence

of waste water is confirmed, we have to maintain a long vigilance to investigate the problem.

J. Rennerfelt and I. Juttander

(Orrje & Co. AB, Stockholm, Sweden and Mo and Domsjö AB, Örnsköldsvik, Sweden)

In connection with Dr. Bartsch's very interesting paper, we would like to report on a similar and even more severe problem in Sweden. The Örnsköldsvik Bay, which is situated at the coast in northern Sweden, receives fresh water from the Moälven River, and is connected with sea by a fairly narrow sound. The municipal wastes from the city (30,000 inhabitants), sulfite mill wastes from the production of about 120,000 tons of pulp per year and hardboard mill wastes are discharged in the bay. In the summer oxygen values are very low and H S production occurs during warm periods.

About twenty years ago, the mill started to make in plant changes to reduce pollution. Although the production has increased steadily, the amount of BOD has been brought down (see Fig. 1). When the mill started with alcoholic fermentation, the BOD was reduced by at least 25 per cent. The next step was the installation of evaporation and burning in 1950 with a BOD reduction of about 60 per cent. In 1960 the mill changed over to sodium base which further reduced the BOD.

At the end of the fifties, the mill started in plant waste surveys and an extensive pollution study in the Örnsköldsvik Bay. At the beginning only temperature, oxygen and H S were measured. Later on the program was extended to other types of analyses as BOD measured as 7 day BOD, permanganate, ammonia, nitrate, nitrite, total nitrogen, phosphate, total phosphorous and sometimes bottom sediments. Samples were taken every week during the summer. Figure 2 shows the concentration of H S at different depths during one year. The highest values were recorded in July, the end of August and the beginning of September. Figure 3 shows that the temperature was high during the same periods and that stratification occurred. This resulted in H S production in the warm surface layers with its rapid decomposition and in the stagnant bottom layers. This observation lead to a survey of the currents at different depths. At least three different currents were found. It was decided to lead out the municipal waste in a different current than the industrial waste to slow down the decomposition of organic matter in the industrial waste which is deficient in nitrogen and phosphorus.

FLOOR DISCUSSIONS

J. L. Stein: What is the significance of oyster larvae work? In 1958 there was an exceptional set in area of study. If your work is correct there should not have been a set. Also, Pacific oysters do not normally set in an area, therefore, why use them in a test?

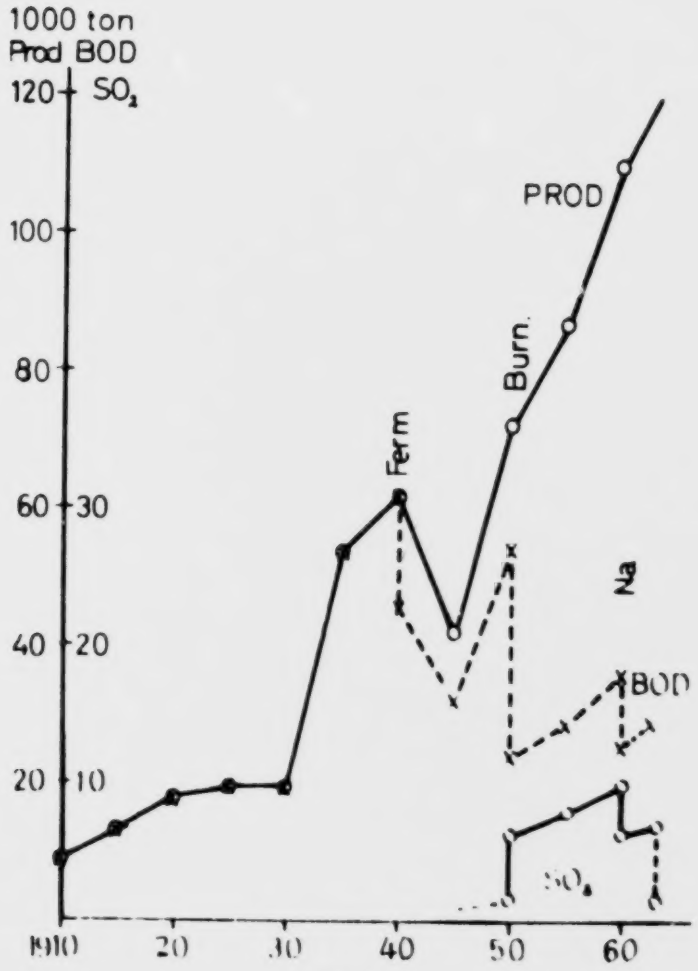
1000 ton
Prod BOD
120
100
80
60
40
20
30
20
10
SO_2
PROD
Burn.
Ferm
Na
BOD
SO_4
1910
20
30
40
50
60

FIG. 1

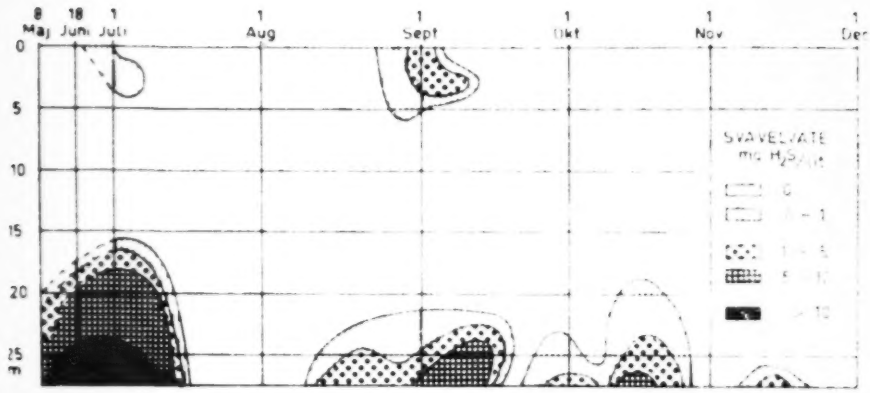
8 Maj
18 Juni
1 Juli
1 Aug
1 Sept
1 Okt
1 Nov
1 Dec
0
5
10
15
20
25
m
SVAVELVÄTE
mg H2S/l
0
0 – 1
1 – 5
5 – 10
> 10

FIG. 2

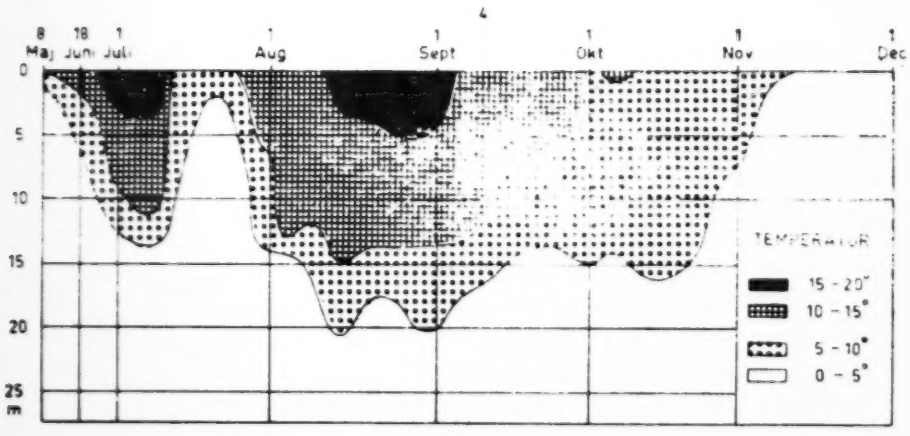
8 Maj
18 Juni
1 Juli
1 Aug
1 Sept
1 Okt
1 Nov
1 Dec
0
5
10
15
20
25
m
TEMPERATUR
15 – 20°
10 – 15°
5 – 10°
0 – 5°

FIG. 3

A. E. BARTSCH: The principal value of the bioassay technique using Pacific oysters is as a most sensitive measure of the presence of pulp and paper mill wastes. Although such oysters are cultivated from seed imported from Japan, occasional sets do occur, such as the notable one in 1958. One might raise the question as to what the effects of pulp and paper mill wastes would be even in such a favorable year. Furthermore, data are not available to show PBI levels in the areas of successful spot set in 1958, so far as I am aware.

I.W. BEAK: Was there any evidence of fish killed in the area corresponding to the points shown in FIG. 6?

A. E. BARTSCH: Fish have been observed to enter the waterfront areas shown in FIG. 6. Some have shown distress and some have been killed. This is the reason the bioassays with juvenile salmon were undertaken.

AUTHOR'S REPLY

DR. NITTA has pointed to the importance of sampling the fish and plankton populations. Although not pointed out in my presentation, bottom fish sampling is being done through cooperative arrangements with the University of Washington. Plankton samples, also are being taken the phyto-plankton samples analyzed by project personnel, the zooplankton samples through cooperative arrangement with Oregon State University.

The comments of Professor MCKEE are well taken. He points to the fact that many studies already have been made in Puget Sound. He cites particularly the hydraulic model of the Sound at the University of Washington. It is pointed out that cognizance has been taken of these past studies in the design of the project study plan. Furthermore, negotiations have been made with the University for use of the model in connection with this work.

He also suggests the importance of 50- and 100-day BOD determinations in connection with the in-plant surveys. I fail to appreciate the significance of such determinations in this case, but agree that determinations of heavy metals, as he suggests, would be especially helpful.

The failure of the fish in site bioassay to have freedom from "avoidance reactions" is pointed out. While the technique does not, indeed, provide such freedom, it should be noted that juvenile salmon do enter the topic zones. Also, studies in 1950 by the Washington Department of Fisheries show that such salmon do not successfully avoid SWL concentrations of up to 1000 p.p.m.

RECEIVED
NATIONAL TECHNICAL
FEB 1973
INFORMATION SERVICE